

Advances in Lithium Ion Technology and Applications

Yet-Ming Chiang

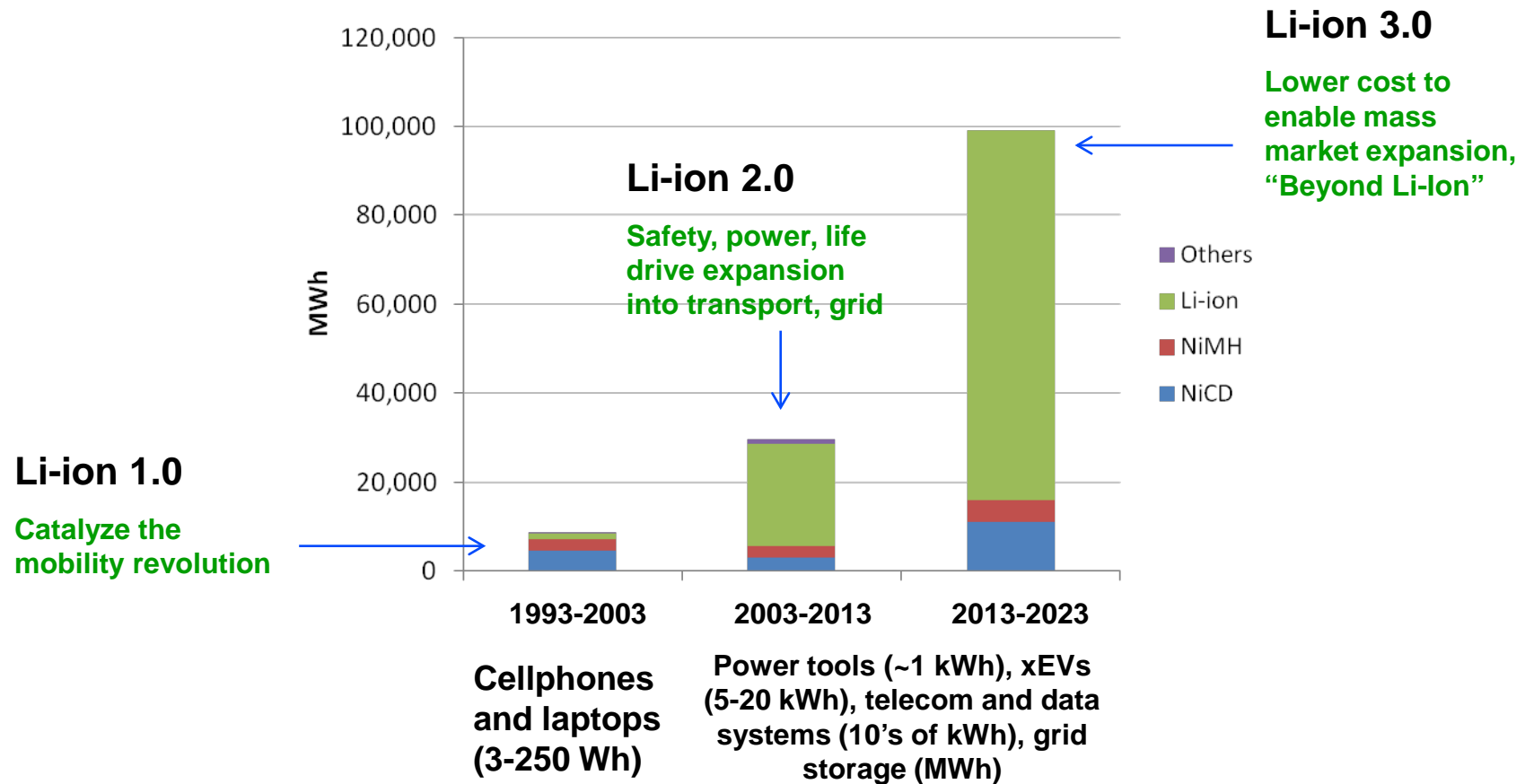
**Department of Materials Science and Engineering
Massachusetts Institute of Technology**



**National Transportation Safety Board
Li-Ion Battery Forum, April 11, 2013**

Li-Ion Since Commercial Inception

Worldwide Growth in Li-Ion





Hybrid City Transit Bus, NYC



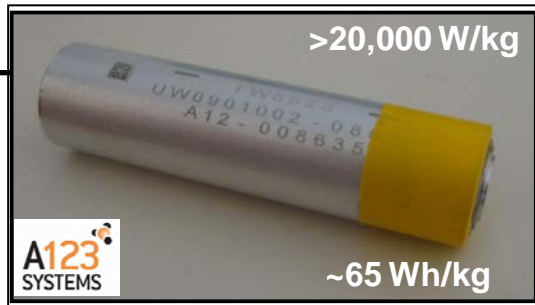
San Francisco

Example of 2nd Generation Success

First On-Road Li-Ion Powered Commercial Production Vehicle (2008)

- 200 kW roof-mounted pack
- 3000 lb weight savings over Pb-acid
- ~3000 buses in service
- 16h per day, 365 days/yr
- > 400 million cumulative road miles driven to date

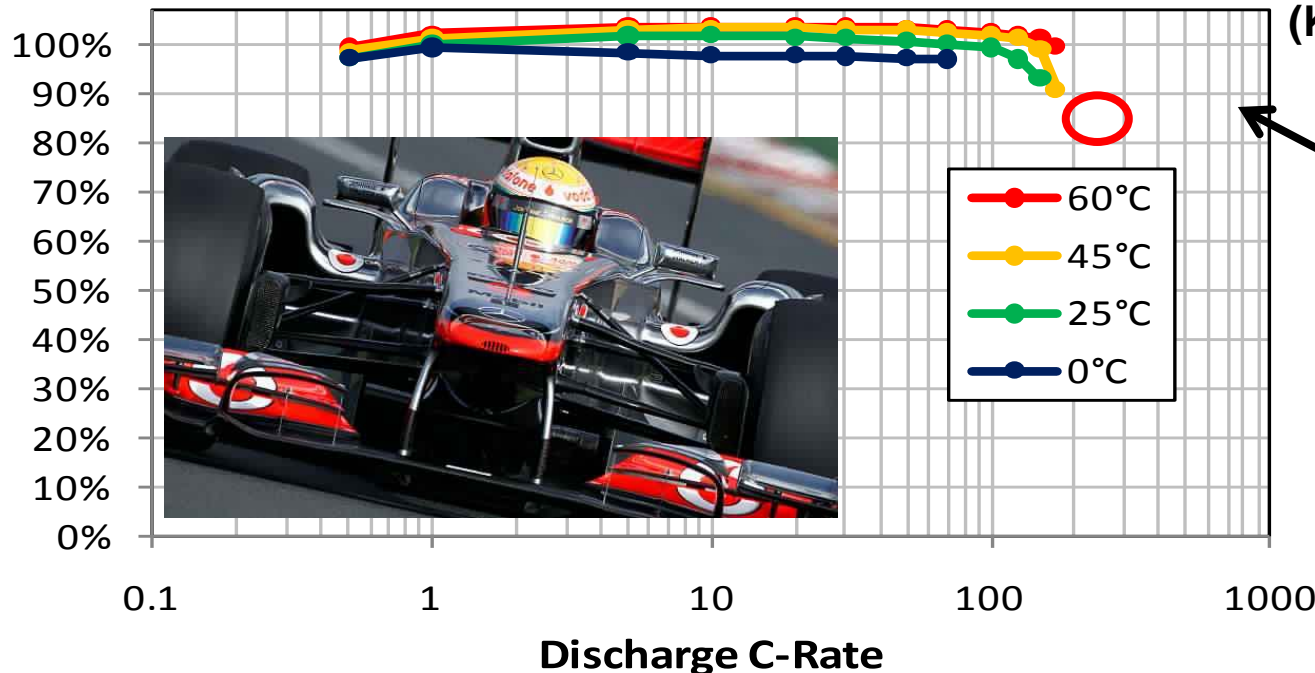
2009: First Li-Ion Hybrid System used in Formula 1 Racing



April 2011: Lewis Hamilton wins Chinese GP using A123 cells

April 2009: Wins first F1 race won by car with regenerative braking (KERS), Hungary Grand Prix

Retention of 1C Discharge Capacity



Race Conditions:
80% of cell energy delivered over 6-8 sec
(250C rate)

2009: World's First Large Scale Li-Ion Storage System in Commercial Service: 12 MW, Los Andes, Chile



2011: Laurel Mountain, West Virginia: 32 MW, 8 MWh of Lithium-Ion Storage Assists Wind Integration

GREEN TECH | 10/27/2011 @ 12:00PM | 5,904 views

The World's Largest Lithium-Ion Battery Farm Comes Online



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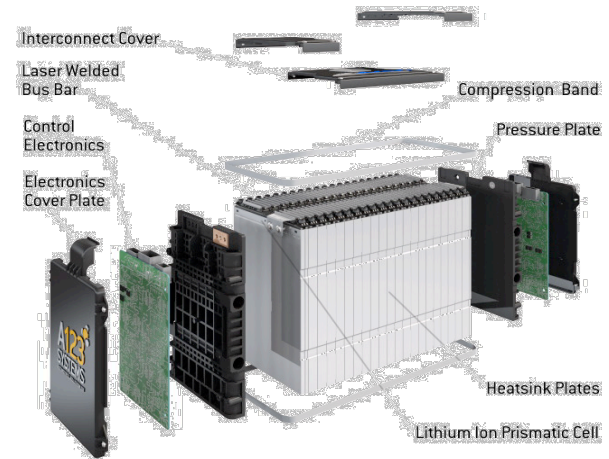
For nearly a month now, a cluster of 53-foot containers on a ridge of Laurel Mountain in West Virginia has been sipping power from wind turbines that stretch out in both directions. The containers are home to the world's largest lithium-ion battery farm for storing and sending energy to the electric grid, and the project reflects the emergence of a technology to help manage the growing production of renewable energy in the country.



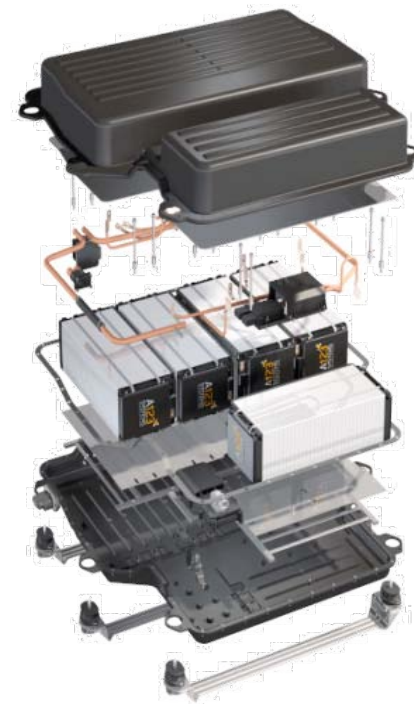
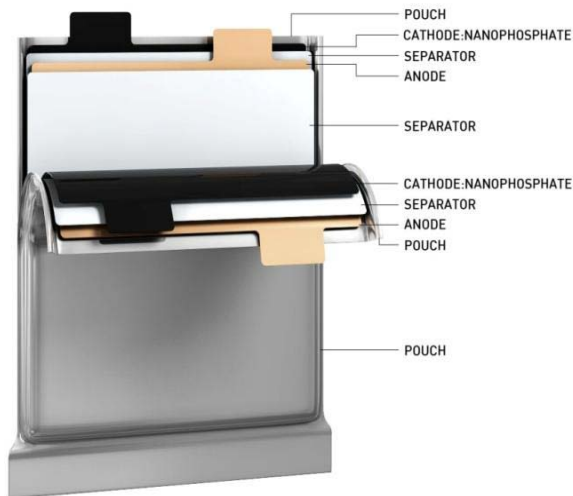
Li-Ion EV Battery Pack Design



**Cylindrical or
Prismatic Cells**



Modules



Packs

Range and Cost: Barriers to Adoption of Li-Ion in EV

Chevy Volt PHEV: 16 kWh (40 mile electric range), \$8K battery, \$41K car



Tesla Model S EV: 85 kWh (~250 mile range), ~\$35K battery, \$85K car

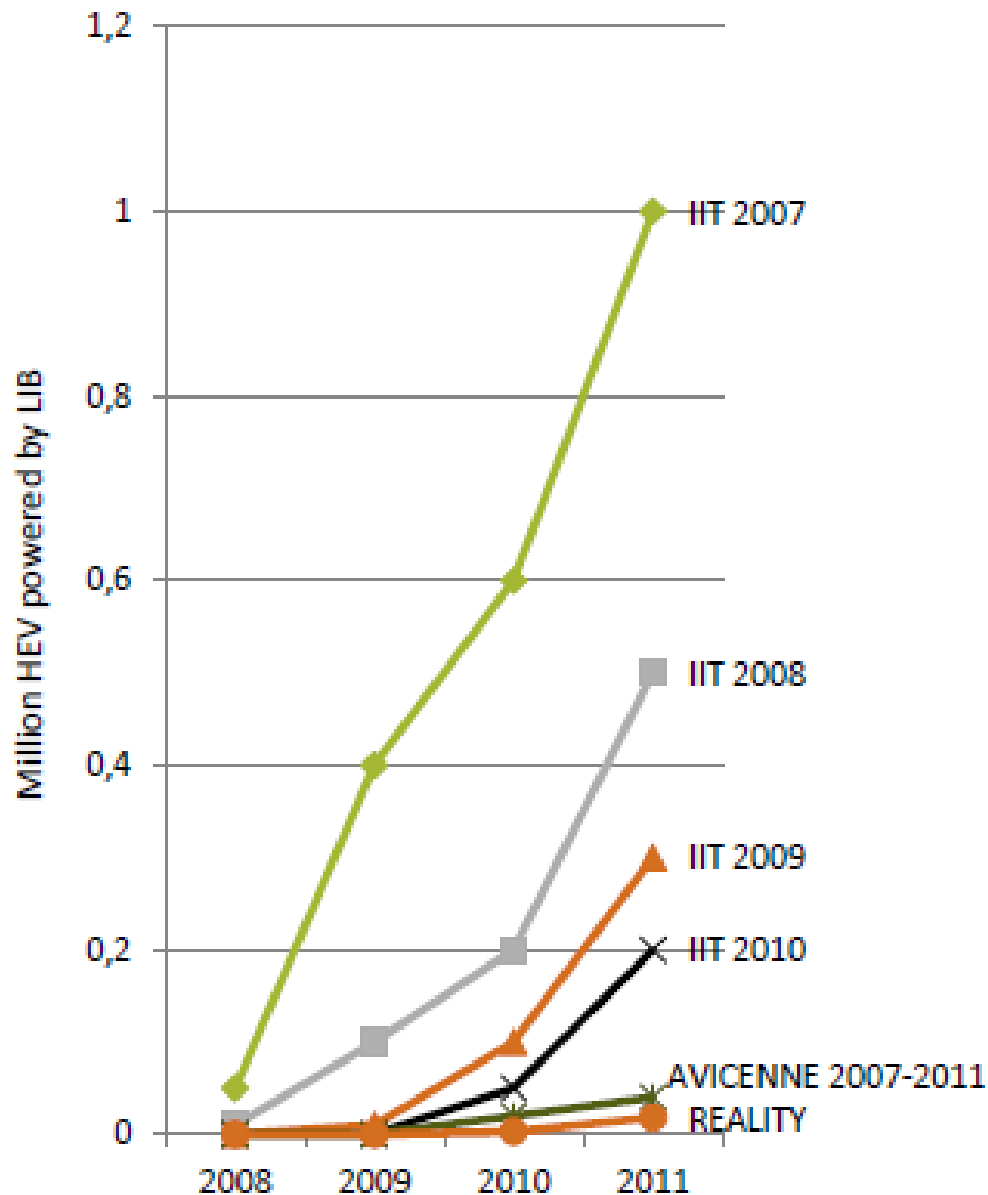


Nissan Leaf EV: 24 kWh (75 mile range), \$12K battery, \$35K car



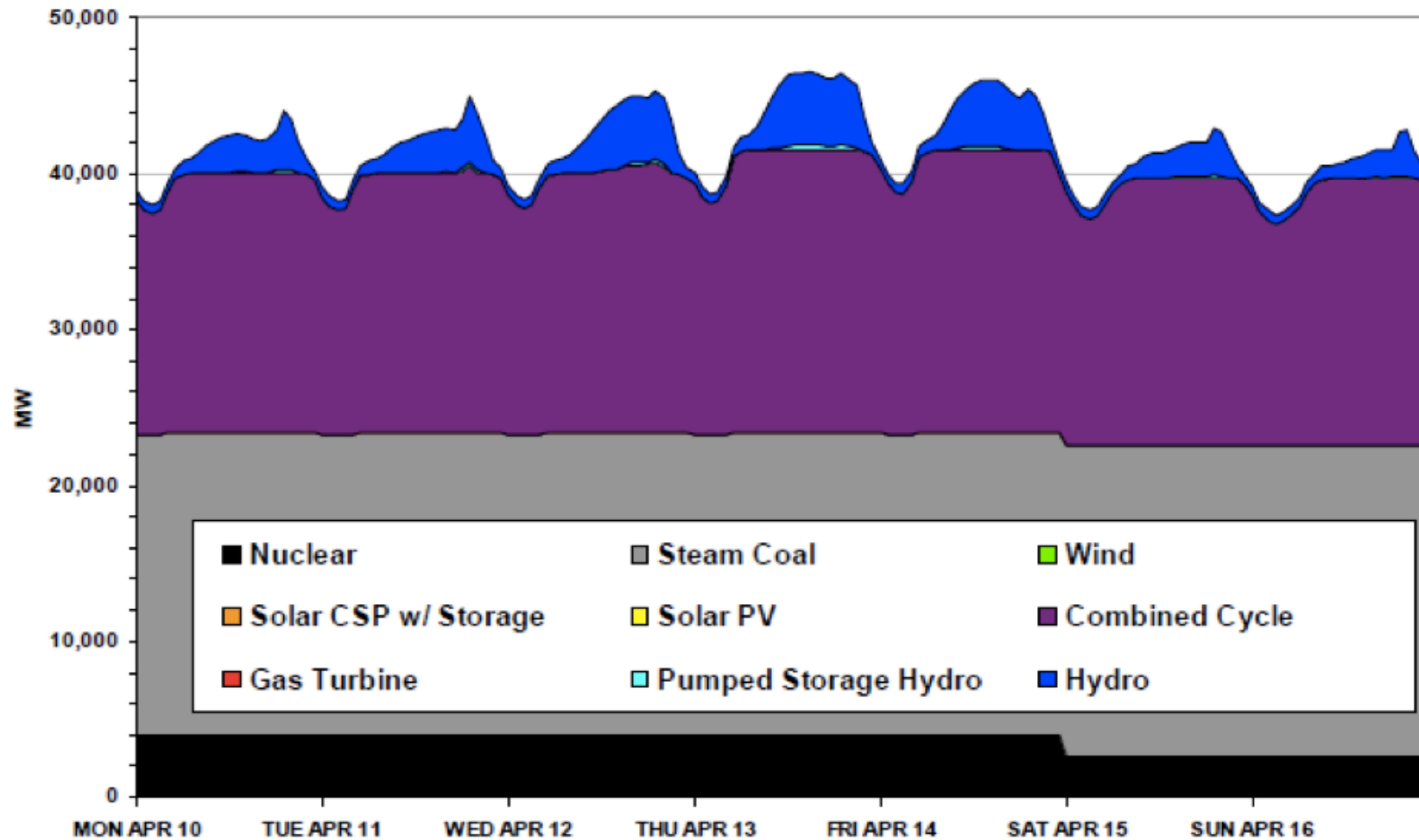
- Energy required: 250-300 Wh/mile
- Today's cost: \$500-600/kWh
- Pack specific energy: 80-100 Wh/kg
- Pack energy density: 200 Wh/L

As a result, Li-Ion Adoption in Transportation Has Not Met Expectations



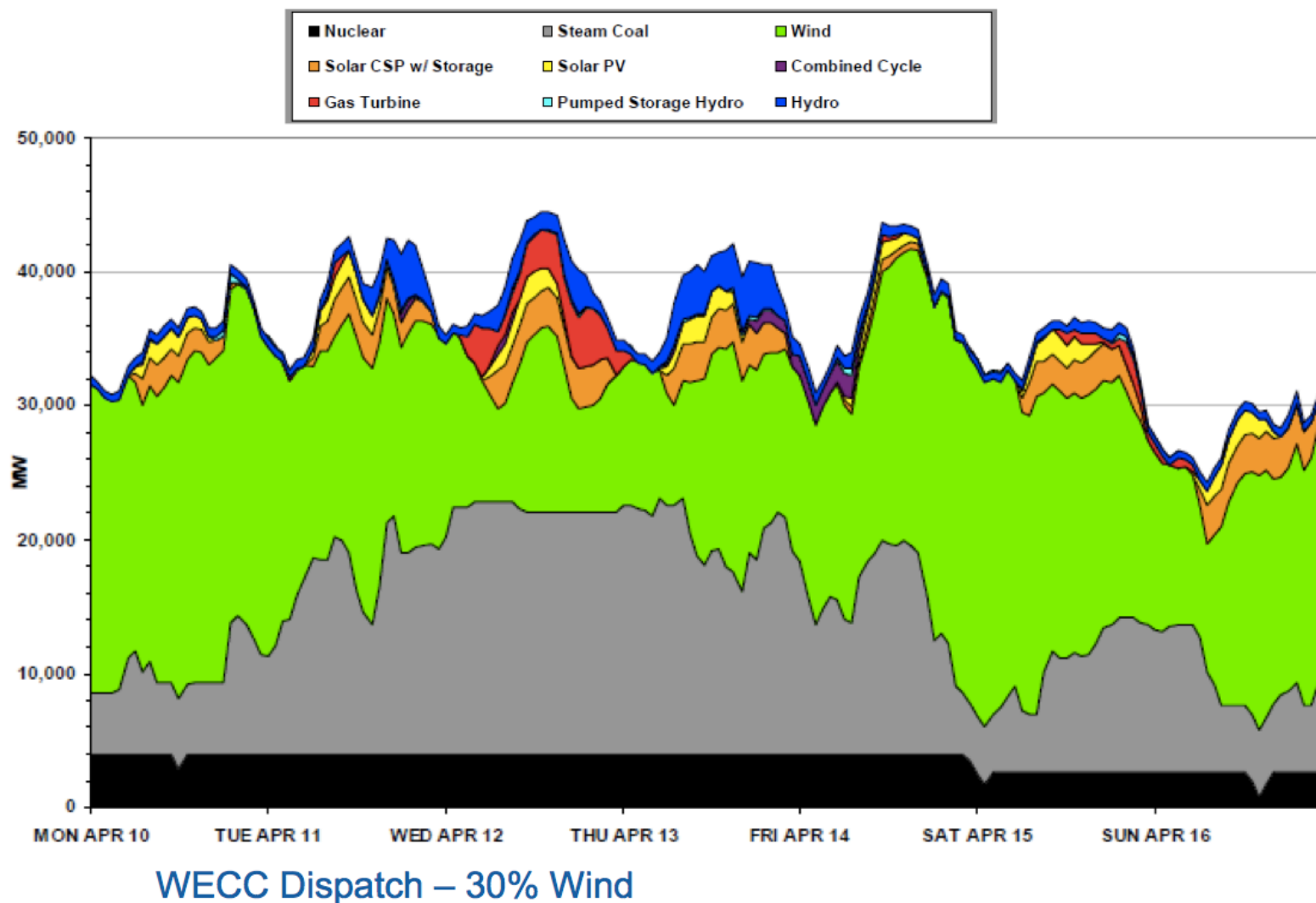
- Projected adoption rates decreased year by year and in the end still was too optimistic
- Many companies built up manufacturing capacity based on such projections
- Currently ~10 GWh/year Li-ion production capacity worldwide is idle (enough capacity for 400,000+ Leafs per year)

Pacific Northwest Today

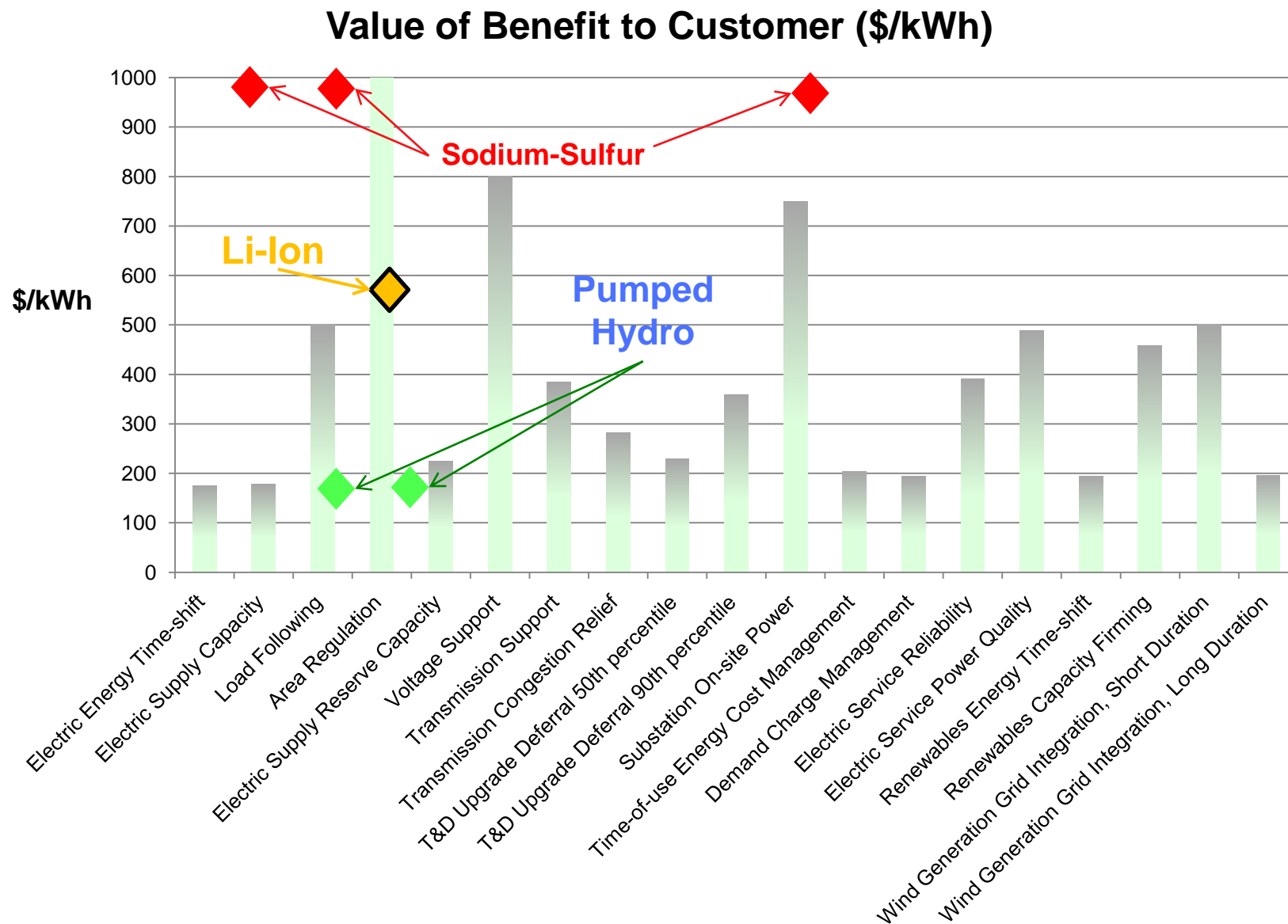


WECC Dispatch – No new renewables

Pacific Northwest with 30% Wind Penetration



Cost is a critical barrier for grid applications



The energy density of electrochemical storage is needed benefit for grid applications



...into this?



...or this?



...or this?



...or this?